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The price path due to order imbalances: evidence from the Amsterdam Agricultural Futures Exchange

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Abstract

The lack of sufficient market depth particularly in many newly initiated futures markets results in relatively high hedging costs, and this inhibits the growth of futures contract volume. In this article the price path due to order imbalances is analyzed and a two-dimensional market depth measure is derived. Understanding the underlying structure of futures market depth provides the management of the futures exchange with a framework for improving their market depth and gives hedgers a better understanding of market depth risk. The managerial implications of our findings are demonstrated empirically using data from the Amsterdam Agricultural Futures Exchange.

Keywords: *liquidity, market depth, dimensions, futures exchange, order imbalances*

JEL classification: $G10$; $G20$

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1. Introduction

A key aspect of futures market performance is the degree of liquidity in the market (Cuny, 1993). The relationship between market depth and futures contract success has been thoroughly investigated in the literature (Black, 1986). A futures market is considered liquid if traders and participants can buy or sell futures contracts quickly with little price effect resulting from their transactions. However, in thin markets, the transactions of individual hedgers may have significant price effects and result in substantial 'transaction costs' (Thompson *et al.*, 1993).

These transaction costs are the premiums that traders are forced to pay or the discounts they are forced to accept in order to establish or close out futures positions (Ward and Behr, 1983). Although, to some extent, hedgers can take positions that offset each other, a futures market if it is to be successful should normally create more market depth in the form of attracting additional traders.

In the literature, liquidity is often synonymous with width, represented by the bid-ask spread for a given number of futures. The bid-ask spread as a measure of liquidity has some limitations. The price may change between the moment the market maker buys and sells, and the trader can earn much more or much less than the spread quoted at the time of the first transaction suggests. Hence, the trader faces costs due to changes in the bid-ask spread. Yet these costs are the essence of market liquidity (Grossman and Miller, 1988). The concept of market depth (the number of securities that can be traded at given bid and ask quotas), an aspect of market liquidity, does not suffer from the limitations of the bid-ask spread, however (Berkman, 1993; Harris, 1990; Kyle, 1985). Therefore, we turn to an examination of market depth.

The objective of our study is to improve insights into market depth and the effect it may have on the performance of futures contracts and, in consequence, on the success of futures exchanges (Pennings and Meulenberg, 1997). In the literature measures of market depth have not explicitly considered the price path produced by temporary order imbalances. Often there is an implicit assumption of linearity and they allow only a limited understanding of the costs associated with lack of market depth. Thus the management of the exchange gets only a limited insight into how the problem of a lack of market depth should be dealt with. In this paper, we propose and parameterize a model that pays explicit attention to the price path caused by temporary order imbalances. When we have more information about these price paths we will be able to distinguish two dimensions of market depth that can be related to the toolbox of the futures exchange (the trading system and trading rules). Evaluating different (competing) futures contracts and futures exchanges along these dimensions can shed light on the performance of the futures contract as a price-risk management instrument. In addition, different trading systems and different trading rules can be evaluated along these dimensions. By doing so we can gain some insight into the performance of trading systems and trading rules.

The article is organized as follows. In Section 2 we describe the concept of market depth. In Section 3 the measures of liquidity and in particular, measures of market depth are examined and Section 4 presents an hypothesis of the underlying structure of market depth from which a market depth price path model is then derived. The remainder of the article is concerned with the application of our model. Section 5 describes the dataset and gives some data transformations. Section 6 presents an analysis of market depth for three selected futures contracts. In Section 7 the managerial implications for the management of the futures exchange are discussed and the results and main conclusions are summarized in Section 8.

2. Market Depth in Futures Markets

Kyle (1985) defines market depth as the volume of unanticipated order flows able to move prices by one unit. Market depth risk is the risk of a sudden price fall or rise due to order imbalances faced by the hedger. This risk seems important to systematic hedgers, particularly in thin markets. Sudden price changes can occur involving both long and short hedges. If a relatively small market sell (buy) order arrives, the transaction price will be the bid (ask) price. For a relatively large market sell (buy) order, several transaction prices are possible, at lower and lower (higher and higher) prices, depending on the size of the order and the number of traders available. If the sell order is large, the price keeps falling to attract additional traders to take the other side of the order. Given a constant equilibrium price, in a deep market, relatively large market orders produce smaller divergences in transaction prices from the underlying equilibrium price than in a thin market. According to Lippman and McCall (1986) the deepness of the market for a commodity increases with the frequency of offers. The generally accepted factors that determine market depth and liquidity in general include the amount of trading activity[1] or the time rate of transactions during the trading period; the ratio of trading activity by speculators and scalpers to overall trading activity; equilibrium price variability; the size of a market order (transaction); expiration-month effect and market structure (Black, 1986; Thompson and Waller, 1988; Christie and Schultz, 1994; Chan and Lakonishok, 1995; Christie and Schultz, 1995).[2] Hasbrouck and Schwartz (1988) find evidence of a relationship between market depth and the trading strategies of market participants. Passive participants wait for the opposite side of their trade to arrive, but the active ones seek immediate transaction. Passive participants may avoid depth costs, whereas active ones generally incur depth costs. Some exchanges monitor temporary order imbalances, i.e., market depth risk, and slow down the trade process if these are present (Affleck-Graves *et al.*, 1994). For example, an order book official issues warning quotas when trade execution results in price changes that are larger than the minimums predescribed by the exchange, and halt trading when order execution results in price changes that exceed exchange-mandated maximums (Lehmann and Modest, 1994).

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[1] In the literature trading activity is often used as an indicator for market liquidity. However, Park and Sarkar (1994) showed that, in the case of the S&P 500 index futures contract, changes in trading activity levels may be a poor indicator of changes in market liquidity.

[2] This list does not pretend to be exhaustive.

3. Measures of Liquidity and in Particular Market Depth

Previous research developed measures of *liquidity* on the basis of indices usually represented by some weighting of trading activity (Working, 1960; Larson, 1961; Powers, 1979; Ward and Behr, 1974; Ward and Dasse, 1977). An important element in these measures are the proportion of hedging to speculative trading volumes. Several researchers (Roll, 1984; Gloston and Milgrom, 1985; Thompson and Waller, 1987; Stoll, 1989; Smith and Whaley, 1994) propose methods for an indirect estimation of liquidity costs. A liquidity cost proxy based on the estimated covariance of prices has been introduced by Roll (1984). Another accepted proxy for the bid-ask spread has been proposed by Thompson and Waller (1988), who argue that the average absolute value of price changes is a direct measure of the average execution cost of trading in a contract. Smith and Whaley (1994) use a method of moments estimator to determine the bid-ask spread. This estimator uses all successive price change data, and assumes that observed futures transaction prices are equally likely to occur at bid and ask.

Market depth measures are rather scarce. Brorsen (1989) uses the standard deviation of the log price changes as a proxy for market depth. Lehmann and Modest (1994) study market depth by examining the adjustment of quotas to trades and the utilization of the chui kehai trading mechanism on the Tokyo Stock Exchange, where the chui kehai are warning quotas when a portion of the trade is executed at different prices. Utilizing the chui kehai trading mechanism can give an indication of market depth, but cannot be used to measure it. Other researchers such as Bessembinder and Seguin (1993) use both price volatility and open interest as a proxy for market depth. Common to all these market depth measures is the fact that they are based on transaction price variability (Huang and Stoll, 1994, 1996) and implicitly assume that the price path due to temporary order imbalances is linear (see, for example, Kyle, 1985). Presumably, the price path will not be linear and particularly so where large orders are concerned. Therefore, we propose a non-linear function which relates the futures price to successive trades.

In the literature there are no measures that reflect the shape of the price path due to order imbalances, while it is this shape that provides insight into the underlying structure of market depth. The underlying structure of market depth is especially relevant to new commodity exchanges in Western and Eastern Europe because of the smaller scale of these exchanges (Kilcollin and Frankel, 1993). Furthermore, the underlying structure of market depth is an important issue for the clearing houses with respect to the system of margining (Gemmill, 1994; Goldberg and Hachey, 1992). Insight into the underlying structure of market depth in combination with improvements in computer and telecommunications technology will lead to improvements in the structure of futures markets and financial institutions in general (Merton, 1995).

4. A Market Depth Model

4.1. *Conceptual model*

Market depth is usually analysed by determining the slope $\mathrm{d}PF/\mathrm{d}Q$, where PF is the futures price and Q is the quantity traded. As outlined in the previous section, current market depth measures are based on transaction price variability and implicitly assume that the price path due to order imbalances is linear. In this section we hypothesize that the price path arising from order imbalances can be characterized by an S-shaped curve. During the occurrence of such an S-curve, the equilibrium price change is assumed to be constant.[3] The price path is downward-sloping in the case of a sell order imbalance and upward-sloping in the case of a buy order imbalance (Working, 1977; Kyle, 1985; Admati and Pfleiderer, 1988; Bessembinder and Seguin, 1993).

We conjecture that the market depth price path consists of four sequential phases, namely (I) a sustainable phase, (II) a lag-adjustment phase, (III) a restoring phase, and (IV) a recovery phase. Although we assume this four phase structure to hold for both upward- and downward-sloping price paths, we confine our discussion to a downward-sloping price path.

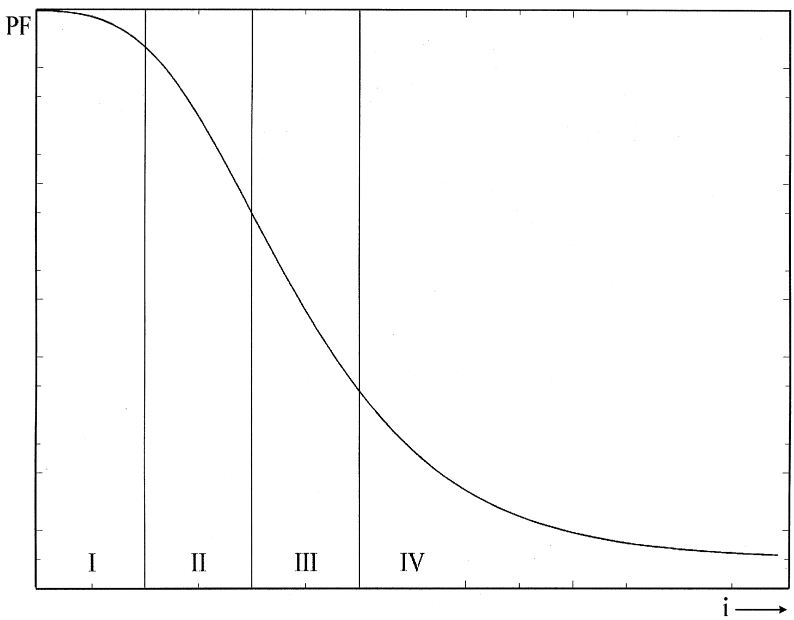

Fig. 1. Price pattern of a sell order in a thin market

Figure 1 depicts the price path of a sell order. On the vertical axis the futures price per contract traded is given. On the horizontal axis the successive contracts traded are given, where the serial number of the futures contract is denoted by i. $i = 1$, is the first contract traded, $i = 2$, is the second contract traded and so on.

[3] There is a large volume of research in the literature (for example, French and Roll, 1986; Fama, 1991; Stein, 1991; Foster and Viswanathan, 1993; Holden and Subrahmanyam, 1994; Oliver and Verrechia, 1994; Hiraki *et al.*, 1995) on information, market efficiency and market liquidity. In these articles, information refers to information relating to fundamental economic factors (supply and demand factors of the underlying 'commodity' of the futures contract traded). Theoretically, we can split price changes into changes due to fundamental economic factors and changes due to the fact that there is a temporary order imbalance. In this study, we concentrate on the latter.

In the *sustainable phase* (Phase I) the first contracts are sold at or near the bid price because of outstanding bids in the brokers' order books. In this phase the already existing bids are almost or completely equal to the first bid price. For that reason, the initial price decline due to order imbalances is very moderate. However, after these bids have been 'used', the price must fall in order to match the next bid in the order book: this point will be called the 'breaking point'. If the price path depicted in Figure 1 is denoted by $PF(i)$, then the breaking point is located where the curvature $[\mathrm{d}^2PF/\mathrm{d}i^2(i)]$ is maximized over i, where $i = 1$ is the first contract traded, $i = 2$ is the second contract traded and so on.

In the *lag-adjustment phase* (Phase II) it is not possible to find enough market depth at a justifiable price. The price falls because bids that have been in the order book for some time (and thus relatively low price bids) are now matched. This gives rise to substantial (compared with Phase I) opportunity costs, gains forgone, because the hedger cannot execute the order at the first bid price (Wagner and Edwards, 1993). Important for the length of this interval and the scale of the price fall is the information provided by the trading system (Keim and Madhavan, 1995). The lag adjustment phase is situated in between the breaking point and the point of inflexion, the latter being located where the slope $[\mathrm{d}PF/\mathrm{d}i(i)]$ is maximized over i.

During the 'lag-adjustment phase' the traders process the price decrease information. They will gradually enter the market after the price has fallen sufficiently (Grossman, 1992). At that moment the *restoring phase* (Phase III) begins. In this phase the prices fall further, but at a decreasing rate. Phase III is situated in between the point of inflexion and the point where the curvature is minimized over i.

In the *recovery phase* (Phase IV) the rate of price decrease slows down fast because more opposite orders enter the market as a consequence of information acquired by the participants. The recovery phase starts at the point where the curvature is minimized over i. It ends where the price reaches the resistance price level.[4] Because the rate of price decrease is slowing down and the price becomes close to the resistance price level, the participants gradually recognize that fundamental economic factors (supply and demand factors of the underlying commodity of the futures contract) cannot be causing the price change. This leads them to conclude that the price change is caused by order imbalances. In this phase participants tend to expect that the price will not fall any further or at least expect that the price will not decrease by more than the minimum tick size (Chordia and Subrahmanyam, 1995). After the resistance price level has been reached, the price will not decrease further because the orders are now balanced.

The market depth price path is caused by frictions in the market structure which includes the trading system and the rules of the exchange. The quality of the market information generated by the trading system regarding high price, low price, last price, size of last trade etc., is crucial for such frictions and hence, for the market depth price path (see Domowitz (1993a,b) for a description of trading systems and their impact on market depth).

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[4] The resistance price level marks the upper and lower boundary between which the price fluctuates according to the participants if the equilibrium price is constant. The equilibrium price is determined by fundamental economic factors.

The S-shaped price path can only be identified *ex post*. Recognized market efficiency theory would suggest that the price would not adjust in a predictable way (Fama, 1991). However, at the moment that the price changes the participants are not able to identify whether the price movement is due to fundamental economic factors causing a change in the equilibrium price or whether it is due to a lack of market depth generated by market frictions caused by the trading system itself.

A priori we do not assume that the downward-sloping S-shaped price path is exactly the reverse of the upward-sloping price path. It is possible, for example, that there are many stop-loss buy orders and hardly any stop-loss sell ones and vice versa, thus causing dissimilarity between upward-sloping and downward-sloping price paths (Chan and Lakonishok, 1993). Nor do we assume the length of the four phases to be equal. In a market that is not able to absorb orders near the equilibrium price, for example, the sustainable phase will become rudimentary.

4.2. *Mathematical specification of the model*

In the mathematical model showing the conceptual model of market depth portrayed in Section 4.1, both sell and buy orders (downward- and upward-sloping price paths) are taken into account. An upward-sloping S-shaped path may well be approximated by a Gompertz curve, since this curve has a non-symmetrical S-shape and thus, does not impose restrictions on the length of the different phases. The Gompertz model is a growth curve and can therefore only be used to describe an upward-sloping price path. However, subtracting a downward-sloping price path from an appropriate constant may establish an upward-sloping price path which will cover the four phases. Consequently, after transforming the data, the price path will always be upward-sloping. We can describe the transformed price series using the Gompertz model given by

$$TPF_i = \alpha \exp(-\beta \exp(-\delta i)), \tag{1}$$

where TPF_i is the transformed price of futures contract i ($i = 0, 1, 2, \ldots, n$) and α, β and δ are positive parameters. Since the price path is restricted to start in the minimum tick size, TPF_0 is equal to the minimum tick size. The parameter β is determined by both α and TPF_0: $\beta = \ln(\alpha/TPF_0)$. The parameters α and δ of the Gompertz model capture two dimensions of market depth. The first dimension, represented by α minus the minimum tick size, indicates how far the price rises (falls) as a consequence of a lack of market depth. The second dimension, presented by δ, has a one-to-one relation with the rate of adjustment, which, as we will show below, is equal to $[1-\exp(-\delta)]$, see Chow (1967) and Franses (1994a,b). This rate of adjustment may be translated into costs in terms of price risk; the futures price may change before actual order execution.

Taking natural logarithms of (1) yields

$$\ln(TPF_i) = \ln\alpha - \beta \exp(-\delta i). \tag{2}$$

A convenient representation of the Gompertz process is obtained by subtracting $\ln(TPF_{i-1})$ from (2) which after some rewriting using (1), gives

$$D\ln(TPF_i) = [1-\exp(-\delta)][\ln\alpha - \ln(TPF_{i-1})], \tag{3}$$

where D is the first order differencing filter defined by $Dz_i = z_i - z_{i-1}$. Equation (3) is of particular interest because it can be interpreted as a partial price

Table 1
Effects on market depth of changes in the two dimensions.

	α increases	δ increases	α increases and δ decreases	α decreases and δ increases
Lack of market depth (in terms of execution costs)	increases	increases	depending on magnitude order flow	depending on magnitude order flow

adjustment model. In order to see this, note that $0<[1-\exp(-\delta)]<1$. As a consequence, although α will always exceed TPF_i, $\ln(TPF_i)$ is rising toward $\ln\alpha$ at a constant rate of adjustment $[1-\exp(-\delta)]$. For instance, if $[1-\exp(-\delta)]=0.1$, it will take many more contracts to achieve a particular price rise than in the situation where $[1-\exp(-\delta)]=0.5$, *ceteris paribus*. Similarly, if $\ln\alpha$ exceeds $\ln(TPF_i)$ by one per cent of $\ln(TPF_i)$, then $\ln(TPF_i)$ will increase by $[1-\exp(-\delta)]\times 100$ per cent. In addition, $\exp(-\delta)$ is the elasticity of TPF_i with respect to TPF_{i-1}.

In terms of the parameters of our model representing the two dimensions this means that an increase (decrease) of both α and δ implies a decrease (increase) of the market depth. Where α and δ have opposite signs we have two counter acting forces. If the order is relatively large the first dimension α is particularly relevant as far as incurring execution costs are concerned. For relatively small orders the second dimension δ is relevant. Table 1 summarizes the effects on market depth of changes in the two dimensions.

The model in (3) may be extended on three fronts. First, Equation (3) is an approximation to the transformed price series. Hence, we add a disturbance term u_i to (3) under the assumption that $u_i \sim \mathrm{IID}(0, \sigma^2 \mathrm{I}_n)$. Second, notice that the transaction-specific price observations cannot be described by a single curve such as the curve depicted in Figure 1, but by a sequence of such curves where an upward-sloping curve is always succeeded by a downward-sloping one and the other way round. As a consequence, the data series on the transformed price consists of a panel (not restricted to being balanced) of upward-sloping curves in chronological order. Third, as discussed in section 4.1, to allow upward- and actually downward-sloping curves to have dissimilar shapes, (3) is extended to:

$$\mathrm{D}\ln(TPF_{ci}) = \pi_s - \tau_s \ln(TPF_{c,i-1}) + u_{ci} \tag{4}$$
$$\text{s.t.} \quad u \sim \mathrm{IID}(0, \sigma^2 \mathrm{I}_N)$$

where $\pi_s = [1-\exp(-\delta_s)]\ln\alpha_s$, $\tau_s = [1-\exp(-\delta_s)]$, $i=1,\ldots,n_c$ with $c=1,\ldots,H$ and s is an index for actually upward- ($s=1$) and downward-sloping ($s=2$) curves. H denotes the number of curves. Notice that our dataset on TPF_{ci} consists of $N=\Sigma_{c=1}^{H} n_c$ observations (i.e., traded contracts), where n_c is the number of contracts per curve c. In the next section more details are given on how we obtain these observations.

4.3. *Estimation of the model*

In our theoretical model we assume that during the occurrence of an S-shaped price path, the equilibrium price is constant and, therefore, the S-shaped price path is attributed solely to temporary order imbalances. However, actual price changes in the futures market result from both temporary order imbalances and from supply and demand factors of the underlying commodity of the futures contract. Consequently, estimation of the model on the basis of real futures market data might invalidate the assumption of a constant equilibrium price during every separate S-shaped price path. However, S-shaped price paths due to temporary imbalances occur in a very short period of time, say within a matter of minutes. Since the effect of fundamental economic factors occurs over a much longer period of time than a few minutes, we might expect that during such a downward-sloping or upward-sloping price path the price change due to fundamental economic factors, i.e. the change of the equilibrium price, is negligible compared to the price change due to order imbalances.

After identifying the individual price paths, we subtract the observations of each downward-sloping price path from the price at which the price path started, such that all curves become upward sloping.[5] In order to eliminate the general price level effect, we shift the curves downward, such that each curve starts at the minimum tick size. Thus, each S-curve, after being transformed to become upward sloping, is shifted downward to the minimum tick size. In doing so we correct for differences in equilibrium price between S-curves. Using the resulting data series, estimates of the dimensions of market depth α and δ are obtained by the following procedure. First, maximum likelihood estimates of π_s and τ_s are obtained by applying ordinary least squares to (4). The maximum likelihood estimates of the relevant parameters α_s and δ_s are computed by $\alpha_s = \exp(\pi_s/\tau_s)$ and $\delta_s = -\ln(1-\tau_s)$. Second, the standard errors of α_s and δ_s are computed by the square root of the diagonal elements of $\mathrm{var}(\eta) = [\partial\eta'/\partial\theta]\,\mathrm{var}(\theta)[\partial\eta'/\partial\theta]'$ (see, Cramer, 1986), where $\eta = (\alpha_1\ \alpha_2\ \delta_1\ \delta_2)'$ and $\theta = (\pi_1\ \pi_2\ \tau_1\ \tau_2)'$ are four-dimensional parameter vectors. Since the maximum likelihood estimators have asymptotic normal distributions, t-values may be used to test if the parameters are significantly different from zero. To see whether one single market depth price path for both upward- and downward-sloping curves suffices, i.e. whether or not the upward-sloping price path is exactly the reverse of the downward-sloping price path, we test the hypothesis H_0: $\{\alpha_1 = \alpha_2 = \alpha$ and $\delta_1 = \delta_2 = \delta\}$. In terms of Equation (4) this implies testing H_0: $\{\pi_1 = \pi_2 = \pi$ and $\tau_1 = \tau_2 = \tau\}$. Since the restrictions are linear we use an F test of which the test statistic has an F (2, $N-4$) distribution, under H_0.

5. Data

In order to illustrate the contributions of the model presented above, we apply it to data from the Amsterdam Agricultural Futures Exchange (ATA). This exchange is one of the largest agricultural futures exchanges in Europe. The trading system employed by the ATA is the open outcry system. There are no

[5] From the data it is not clear where the exact split between an increasing and decreasing price path should be imposed when two or more contracts in between are traded at the same price. Therefore, to determine the split we apply the following procedure: for an odd number of contracts traded at the same price we use the middle contract, and for an even number of constant contracts we employ a random assignment with equal probabilities.

scalpers on the trading floor and all orders enter the trading floor via brokers. Brokers are only allowed to trade by order of a customer. There is no central order book on the ATA. The broker only has insight into his/her own order book. The customer (hedger or speculator) has no information on outstanding orders.

Potatoes and hogs are traded on the ATA. The potato futures contract is a relatively successful one in the sense that the volume generated (about 200,000 contracts annually) is large relative to competitive potato contracts elsewhere in Europe (such as the potato futures traded on the London Commodity Exchange and on the Marché à Terme International de France). The annual volume is small, however, when compared with agricultural futures traded in the United States. Hog futures are not successful as far as their volume (about 30,000 contracts annually) is concerned. The minimum tick size for the potato and hog futures contracts equals 0.10 Dutch guilders and 0.005 Dutch guilders, respectively.

We use real-time transaction-specific data for three futures contracts: potato contract delivery April 1996, and hog contract deliveries August and September 1995.[6] Descriptive statistics for both the potato and hog futures price and volume series are presented in Table 2. The average number of contracts per trading day is relatively large for the potato market compared with the hog markets. The

Table 2
Descriptive statistics of the real-time transaction-specific futures prices.

	Futures contract		
	Potato delivery April 1996	Hog delivery August 1995	Hog delivery September 1995
Number of observations (i.e. contracts traded)	46791 (April '95– August '95)	2742 (February '95– August '95)	2317 (February '95– August '95)
Average number of contracts per trading day	503	24	22
Average price per contract[a]	43.4	2.330	2.265
Standard deviation of the price	18.0	0.150	0.120
Minimum price	21.7	2.065	2.060
Maximum price	79.0	2.655	2.650

[a]The futures price for potatoes is quoted in Dutch Guilders per 100 kilogram whereas the hogs are quoted in Dutch Guilders per kilogram live weight.

[6]The reason that we investigate these three futures contracts is a practical one. In order to estimate the model we had to obtain transaction-specific data. These data were gathered by the exchange on our request. Normally the exchange only saves the daily close price, high price, low price and traded volume. We were able to receive transaction-specific prices only for the three futures contracts investigated in the paper.

latter market faces severe problems of market depth which inhibits its contract growth.

6. Empirical Results

In this section we apply ordinary least squares to (4) and express the estimates of π and τ in those of α and δ.

In Table 3 the estimation results for the potato futures contract, delivery April 1996, are displayed. It can easily be seen that all parameter estimates are significantly greater than zero when using a one-sided t-test and a 0.05 level of significance. The Durbin-Watson statistic does not indicate any mis-specification. In spite of its low value, the R^2 is significantly greater than zero, as indicated by the $F(3, 46786)$ statistic. The hypothesis H_0: $\{\alpha_1 = \alpha_2 = \alpha$ and $\delta_1 = \delta_2 = \delta\}$ is rejected. Therefore, the market depth for the potato futures contracts, delivery April 1996, significantly differs between periods of price rise and price fall.

Table 4 presents the estimation results for the hog futures contract, delivery August 1995. Since the hypothesis H_0 cannot be rejected, we conclude that the market depth for this contract is characterized by a single Gompertz curve. So, the upward sloping price path is the reverse of the downward sloping price path. Compared with Table 3, the statistics in Table 4 lead to similar conclusions with respect to the performance of the regression.

Table 5 shows the estimation results for the hog futures contracts, delivery September 1995. The results are quite similar to those in Table 4. Again, we cannot reject H_0.

7. Discussion

We will now discuss how the management of the exchange can use our empirical results to improve the performance of the futures exchange with regard to its market depth. For this purpose, we draw the Gompertz curves for the upward-

Table 3
Estimates of the parameters describing the underlying dimensions of market depth of the potato futures contract, delivery April 1996.

Contract		Parameter estimates Gompertz curve[1]			
		α		δ	
Potatoes futures contracts, delivery April 1996	downward sloping	1.374 (0.057)		0.053 (0.002)	
	upward sloping	1.013 (0.053)		0.060 (0.002)	
Number of observations	46790				
R^2	0.099	Probability of $F(3, 46786)$		<0.001	
$F(3, 46786)$	638	Durbin-Watson statistic		1.914	
$F(2, 46786)$ for H_0: $\{\alpha_1 = \alpha_2 = \alpha$ and $\delta_1 = \delta_2 = \delta\}$	7.760				
Probability of $F(2, 46786)$	<0.001				

[1] standard errors in parentheses

Table 4
Estimates of the parameters describing the underlying dimensions of market depth of the hog futures contract, delivery April 1995.

Contract			Parameter estimates Gompertz curve[(1)]	
			α	δ
Hog futures contracts, delivery August 1995			0.039 (0.016)	0.159 (0.009)
Number of observations	2741			
R^2	0.249	Probability of $F(1, 2739)$		<0.001
$F(1, 2739)$	348	Durbin-Watson statistic		1.811
$F(2, 2739)$ for H_0: $\{\alpha_1 = \alpha_2 = \alpha$ and $\delta_1 = \delta_2 = \delta\}$		0.217		
Probability of $F(2, 2739)$		0.805		

[(1)] standard errors in parentheses

sloping and downward-sloping potato futures price path (see Figure 2) and for the hog futures price paths (see Figure 3), using the parameter estimates in Tables 3, 4 and 5. In each of the two figures both dimensions of market depth are visualized simultaneously. Note that since the upward-sloping price paths for both deliveries of hog are the reverse of the downward-sloping price paths, we only depict the upward-sloping price paths for both hog series in Figure 3.

The upward- and downward-sloping Gompertz curves for *potato* futures have dissimilar shapes. The first dimension—indicating how far the price falls or rises due to order imbalances—is quite large compared with the general price level. This might be due to the absence of scalpers. In order to improve the absorption capacity, the ATA might consider allowing scalpers on the floor. The second dimension—the rate of price change—is higher for the upward-sloping price path than for the downward-sloping price path. This can be explained by the fact

Table 5
Estimates of the parameters describing the underlying dimensions of market depth of the hog futures contract, delivery September 1995.

Contract			Parameter estimates Gompertz curve[(1)]	
			α	δ
Hog futures contracts, delivery September 1995			0.044 (0.022)	0.115 (0.008)
Number of observations	2314			
R^2	0.200	Probability of $F(2, 2312)$		<0.001
$F(1, 2312)$	348	Durbin-Watson statistic		1.855
$F(2, 2312)$ for H_0: $\{\alpha_1 = \alpha_2 = \alpha$ and $\delta_1 = \delta_2 = \delta\}$		0.136		
Probability of $F(2, 2312)$		0.873		

[(1)] standard errors in parentheses

that there are differences between the number of stop-loss buy and stop-loss sell orders. The difference between the numbers of stop-loss buy and stop-loss sell orders can be explained by the fact that participants in the potato futures market consist of relatively large firms (potato processing industry) who are the net buyers of potato futures contracts on the one hand and relatively small firms (potato farmers and small potato traders) who are net sellers of potato futures contracts on the other. The former participants often use stop-loss buy orders especially because they normally make cash forward contracts with retailers regarding potato products (such as chips and french fries). Where the price rises we observe a trigger effect: a considerable number of stop-loss buy orders are executed which push the price upwards and thereby reinforce the stop-loss buy order effect which causes an acceleration of the price of futures. The potato farmers and small traders usually do not use stop-loss sell orders, but wait until the price is satisfactory and then enter the futures market.[7]

Since the curves in Figure 2 do not intersect, we may conclude that the futures market is deeper in the case of a sell order imbalance than in the case of a buy

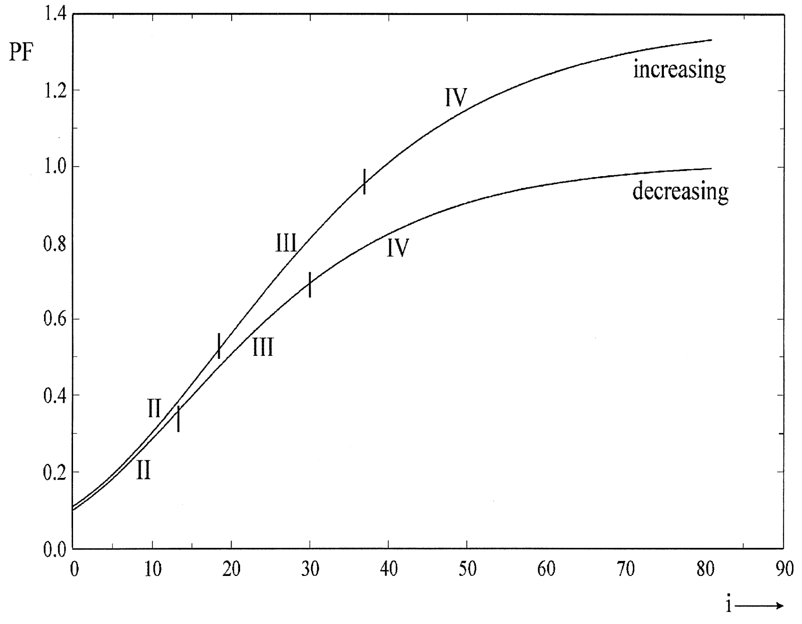

Fig. 2. The Gompertz curves for the potato futures contract delivery April

The figure depicts the Gompertz curves for increasing and decreasing price paths. On the vertical axis the futures price per contract traded is given. On the horizontal axis the prices of successive contracts traded are given, where the serial number of the futures contract is denoted by *i*. $i = 1$, is the first contract traded, $i = 2$, is the second contract traded and so on.

[7] We acknowledge the information we received on this subject from the brokers at the Amsterdam Agricultural Futures Exchange.

order imbalance. The problem of the high rate of (adverse) price changes at the ATA might be solved by implementing a mechanism for slowing down the trade process if order imbalances do occur and to improve market depth by reporting these. Also the order book information can be improved. At the ATA, the order books of the different brokers are not linked and the customer has no information with regard to outstanding orders. An order book mechanism that allows potential participants to view real-time limit orders, displaying the desired prices and quantities at which participants would like to trade, will improve the rate of adjustment and the distance between the lower and upper bounds.

The upward- and downward-sloping price paths are similar for both *hog* deliveries. In the hog futures market we observe a symmetry between stop-loss buy and stop-loss sell orders in contrast to the potato futures market. Tables 4 and 5 show that α is smaller for delivery August than for delivery September indicating that the delivery August performs better on the first dimension. However, on the second dimension delivery September performs better than delivery August (i.e, δ for delivery September is smaller than for delivery August). Consequently we observe in Figure 3 that the price paths intersect, indicating that for relative small orders September delivery is deeper than August, whereas for large orders August delivery is deeper (see also Table 1).

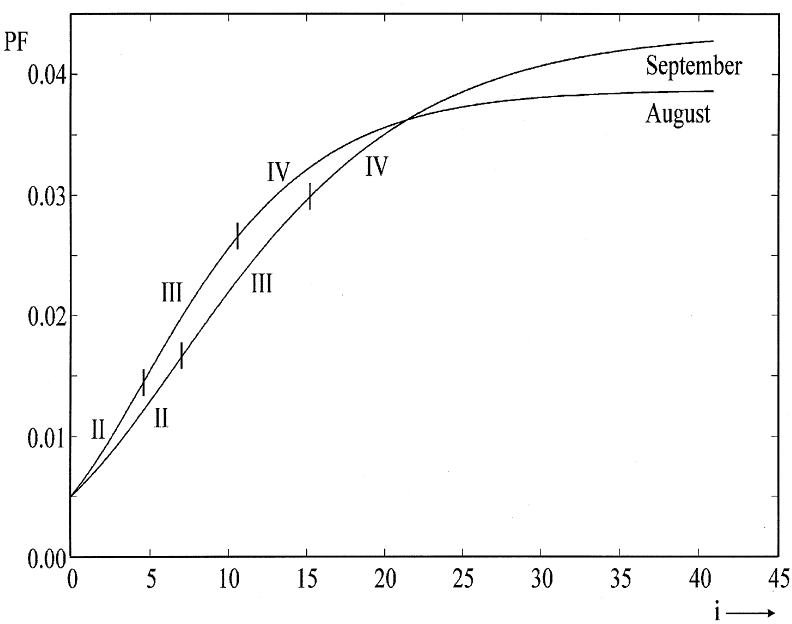

Fig. 3. The Gompertz curves for hog futures contracts deliveries August and September

The figure depicts the Gompertz curves for hog delivery August and hog delivery September. No distinction is made between upward- and downward-sloping price paths, because the upward sloping price path is exactly the reverse of the downward sloping price path. On the vertical axis the futures price per contract traded is given. On the horizontal axis the successive contracts traded are given, where the serial number of the futures contract is denoted by *i*. $i = 1$, is the first contract traded, $i = 2$, is the second contract traded and so on.

8. Conclusions and Further Research

In contrast to the existing market depth measures, we conjecture that the market price depth path has an S-shape in which four phases can be distinguished: the sustainable price phase, the lag-adjustment phase, the restoring phase and the recovery phase. This S-shaped price path may well be approximated by the Gompertz curve, which allows for a non-symmetrical S-shape and hence, does not impose certain restrictions on the length of the different phases. The two parameters of our model represent two dimensions of market depth. The first dimension represents the distance between the upper and lower bounds, i.e. indicates how far the price falls (rises) due to a lack of market depth. The second dimension indicates the rate at which price falls or rises. Our market depth measure has convenient characteristics. First, it provides insights into the underlying structure of market depth and gives guidelines for improving market depth. Second, our measure can be used to compare competitive futures contracts. Third, the market depth model is estimated with simple regression techniques. Furthermore, since our measure can be presented in a graphical way, it is relatively easy to interpret.

We applied the model to the potato and hog futures traded on the Amsterdam Agricultural Futures Exchange. We found that both the distance between the upper and lower bounds of the price path and the rate of the price change is high, indicating a lack of market depth. The current trading system—no scalpers and no central order book information—contributes to this situation. Redesigning the trading system in order to lower the distance between the upper and lower bounds of the price path and the rate of the price change is recommended.

When interpreting the results, it is important to be aware of the following points. First, as we have indicated, our model requires transaction-specific data. Transaction-specific data enable us to identify individual downward-sloping price paths and individual upward-sloping price paths by assuming that each of these price paths ends when the traders expect that price will not change by more than the minium tick size, and that during each price path, which takes place over the space of a few minutes, price change due to fundamental economic factors will be negligible compared to the price change due to order imbalances, i.e. we may expect that over such a short period of time the equilibrium price does not change.

Second, our research is restricted to one futures trading system. In order to draw conclusions with respect to the relation between the two distinguished market depth dimensions and the futures market structure, other futures trading systems should be incorporated into the analysis. Measuring the market depth dimensions for different kinds of trading systems provides more information as far as the relationships between the market depth dimensions and the different elements of trading systems are concerned. Research addressing these two points should be an interesting avenue to explore in the future.

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